Canada. Hydrographic and Map Service

Currents of the Gulf of St. Lawrence, including the Anticosti Region, Belle Isle and Cabot Straits.

1900

THE CURRENTS

IN THE

GULF OF ST. LAWRENCE

INCLUDING THE

ANTICOSTI REGION BELLE ISLE AND CABOT STRAITS

SED FROM THE REPORTS OF THE SURVEY OF TIDES AND
URRENTS, FOR THE SEASONS OF 1894, 1895 AND 1896

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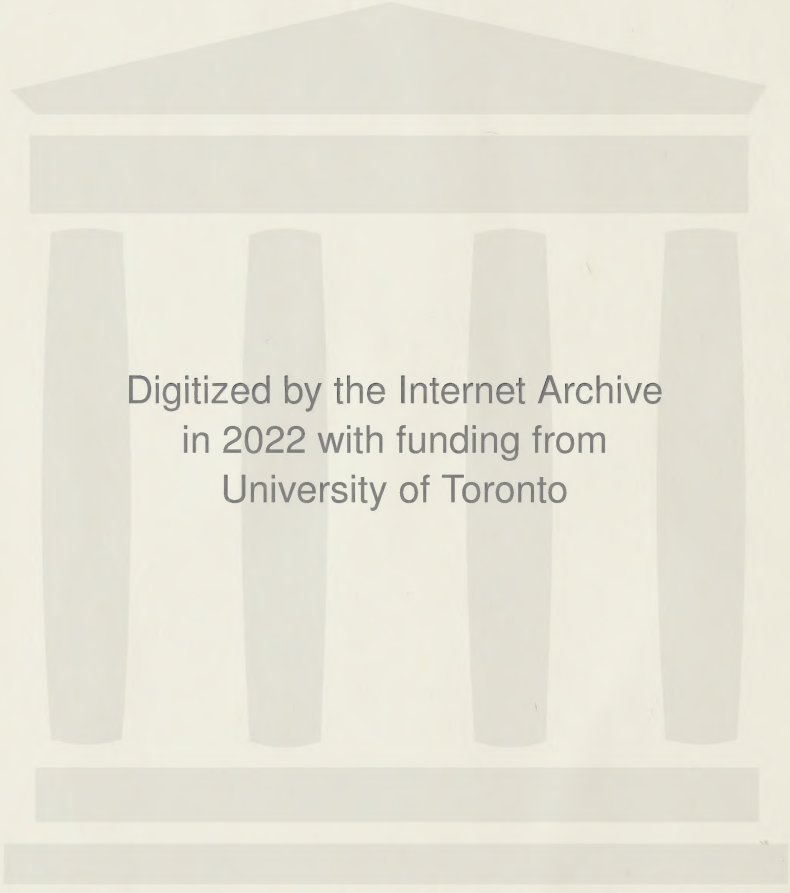

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PREFACE.

The information herein contained, is derived from investigations in the Gulf of St. Lawrence, by the Survey of Tides and Currents, of the Department of Marine and Fisheries of the Dominion of Canada. The investigations were made by Mr. W. Bell Dawson, C.E., in charge of the Survey, during the summer months of 1894, 1895, and 1896; and they are supplemented by information collected personally by him, from captains of vessels, fishermen and others, having a long experience in the Gulf.

In the investigations, a steamer was employed. It was anchored in positions carefully selected for the purpose in view. These were in all depths, up to 250 fathoms. The steamer thus served as a fixed point from which to observe the behaviour of the current. The observations of the current, and of the force and direction of the wind, were continuous day and night. For the methods and appliances employed in measuring and tracing the currents, see reports of the Tidal Survey for the above years.

The examination of the currents was made chiefly along the lines of the leading steamship routes which traverse the Gulf. The speed of the current was measured, in all cases, at a depth of 18 feet. The directions given are magnetic throughout. The varation is from 26° to 35° westerly.

A continuous record of the tide itself was obtained simultaneously for comparsion with the currents, at tidal stations in the region, established by this Survey. Observations of wind and barometer were also secured at the permanent Meteorological stations.

The following arrangment of the information has been adopted:—

Part I.—Description of the currents on the surface, as a mariner may expect to find them in each locality.

Part II.—The causes, as far as ascertained, which influence the currents in moving as they do; and the general circulation of the water in the Gulf of St. Lawrence.

This second part is also of value to mariners, in showing the usual direction in which the water tends to move, when undisturbed.

GENERAL DESCRIPTION

OF

THE GULF AND RIVER ST. LAWRENCE.

From Montreal at the head of ocean navigation, to Quebec, may be termed the St. Lawrence River; and from Quebec to Point de Monts, the Lower St. Lawrence. The Gulf of St. Lawrence thence extends to Cabot Strait, between Cape Breton Island and Newfoundland. It opens into the ocean by this strait, which has a width of 65 miles and a depth of 250 fathoms; and by Belle Isle Strait which has a width of 11 miles and a depth of 30 fathoms.

The area of the Gulf is traversed by a deep channel which runs from the mouth of the St. Lawrence past the Gaspé coast, and crossing the open Gulf to the north of the Magdalen Islands, passes out through Cabot Strait. Thence it continues south-eastward, dividing St. Pierre bank on the north from Banquereau and Misaine bank on the south, till it reaches the edge of the deep Atlantic basin. A branch from this channel also runs for some distance into the north-eastern arm of the Gulf, towards Belle Isle.

The depth of this channel increases from 150 fathoms at the mouth of the St. Lawrence to 250 fathoms in Cabot Strait. It forms the main avenue by which the tides of the Atlantic enter the Gulf and travel across it to the mouth of the St. Lawrence; whence they continue with ever increasing height to Quebec. Above Quebec the tide is still felt as far as Three Rivers.

PART I.

NATURE OF THE CURRENTS IN THE GULF AREA.

General Character.—These currents are of two kinds ; (1) Constant currents which run more or less continuously in accordance with the general circulation of the water in the Gulf area ; and (2) Tidal currents, which are produced or chiefly influenced by the tide. Both classes of currents are affected by the wind ; the prevailing direction of the wind being west and south-west in summer, and north-west in winter.

Speed.—With the exception of the currents in the various straits and near the heads of the bays, the currents met with in the open Gulf seldom exceed one knot per hour. They are therefore the more easily influenced by strong winds, especially at the surface of the water. Currents which have a greater speed than this, are found in Belle Isle and Cabot Straits, in Northumberland Strait, off the Gapsé coast, in the Gut of Canso, and locally in channels between islands and at the mouths of rivers.

Water.—The water of the Gulf may be roughly divided by a line running from South-west Point of Anticosti, to the middle of Cabot Strait. Along the south-western side of this line, the water has a lower density ; as it is apparently made a little fresher by the outflow of the St. Lawrence River. To the north-east of this line, throughout the north-eastern arm of the Gulf, the water has the same density, or saltness, as in the open Atlantic.

Constant currents.—The general drift of this water of lower density is outward, towards the Atlantic. This gives rise to two constant currents, one at the mouth of the St. Lawrence along the Gaspé coast, which may be called the 'Gaspé Current,' and the other on the west side of Cabot Strait around Cape North, which may be called the 'Cape Breton Current.' A third constant current is found on the west side of Newfoundland, making north-eastward from the Bay of Islands towards Rich Point.

It is to be noted that in calling these currents constant, it is only meant that they usually or most frequently run in the one direction. During certain winds, they may be much disturbed, or their flow may be checked, as will be seen when their behaviour is more fully explained.

Tidal currents.—The strongest of the tidal currents are found on the Lower St. Lawrence, where in places they attain a speed of five or six knots per hour. Also, the tidal current in the Gut of Canso runs at four knots ; and in the narrowest part of Northumberland Strait, off Cape Jourmain, at three knots per hour. The currents in these localities have not been examined by this Survey, however.

The tide has a distinct influence upon nearly all the currents in the Gulf area. It may cause a variation in speed when the current runs in one direction, or the direction of the current may veer with more or less regularity in accordance with the tide. The effect of the tide in these respects will be explained when the various localities are described.

THE GASPÉ CURRENT.

The following description of the behaviour of this current, refers chiefly to the region extending from Fame Point to Cape Gaspé ; as it is there that vessels make and leave the Gaspé coast on all the trans-Atlantic and Gulf routes which lead into the St. Lawrence. It is based upon investigations in July and September, in 1895.

The usual current.—While ordinary weather prevails, the current in the offing of the Gaspé coast runs constantly outwards to the S.E. and S.S.E. (magnetic). It usually occupies a belt of about 12 miles in width lying from 2 to 14 miles off shore, in the vicinity of Fame Point. This belt appears to become narrower and the current stronger towards Cape Rosier ; and between it and the shore there is a tidal current in both directions, as shown on the Admiralty Chart No. 1621, entitled 'Entrance to the St. Lawrence.' In passing Cape Gaspé it keeps closer to the shore, cutting off the in-shore tide, and its direction there varies from S.S.E. to S.S.W. This current past Cape Gaspé was found to be constant during very varying conditions of the current elsewhere. The speed of the current usually ranges from one to two knots ; the highest observed being 2·81 knots per hour.

Displacement of the current.—The main current setting south-east, was found at times to lie in the middle of the passage between the Gaspé coast and Anticosti ; and to have approximately the position shown by the line along the middle of the passage marked 'Constant Current' on Admiralty Charts Nos. 2516 and 1621. The current does not appear to be felt on the Anticosti side, however.

When the current is in this position, the area between it and the Gaspé coast may be occupied by weak and fluctuating currents, or even by a reverse current setting inwards. This position of the current in the middle of the passage may therefore be regarded as a displacement of the current, or an alternative route which it may take.

Reversal of the current.—A reverse current may set inwards to the north-west along the Gaspé coast at times when the main current takes the above route along the middle of the passage. Such a current, in the offing of Fame Point, may occupy a belt lying between 2 miles and 12 miles from shore, and may run constantly to the north-west for as much as six days, with a speed which ranges from 0·50 to 1·40 knots per hour. This reverse current may thus occupy the site of the usual outward current along the Gaspé coast ; but while this takes place, the current past Cape Gaspé still runs southward, and its direction will probably be a little west of south.

Off and on-shore directions of the current.—It is possible for the current while undergoing the above changes, to veer in direction, and thus to set directly off or on shore for a few hours at a time.

Tidal influence.—When the current runs constantly in one direction, whatever position it may take, and whether it runs with its usual outward direction or is reversed, it is always subject to a fluctuation in speed which corresponds with the tide. When the current has its usual south-eastward direction, or outwards from the St. Lawrence to the Gulf, it is strongest at low water and weakest at high water ; but when the current runs inwards the reverse is the case.

Influence of the wind.—It appears probable that the chief reason that the current keeps along the Gaspé coast is because the prevailing winds on the Lower St. Lawrence are towards the south-east side. When the winds are north-westerly in the Gaspé region also, they assist in keeping the current along that shore, and tend to increase its speed. On the other hand the current appears to be kept away from the coast, and to be most disturbed when the winds are from the southward of west (magnetic) on the Lower St. Lawrence, and at the same time south or south-east in the Gaspé region. The winds then blow in upon both ends of the waterway which forms the entrance to the St. Lawrence, and they have an off-shore direction along that part of the coast which the Gaspé current usually follows. The winds can only have the above directions in these regions, when a low pressure area or storm-centre is travelling along a course which lies to the northward of the St. Lawrence valley.

This northern course for an area of low pressure is less frequent; as the usual path of storms lies to the south of the St. Lawrence valley, or along the Atlantic sea-board. The conditions above indicated are therefore unusual; and if the displacement and reversal of the Gaspé current are dependent upon them, it is clearly correct to consider these conditions of the current itself as exceptional.

It may therefore be said in general, that vessels may expect to find the usual outward current, setting south-east along the Gaspé coast, unless they have reason to infer from the weather they meet with, that a low pressure area or storm-centre is passing to the northward. This would probably be accompanied by winds to the southward of west along the Lower St. Lawrence; and southerly winds with a falling or low barometer at the entrance to the St. Lawrence south of Anticosti. The condition of the current will then be disturbed; and its course altered, or its direction reversed, as above explained.

Vessels making inwards, especially if the weather is foggy, must not count too definitely however, on the absence of the outward current as an assistance in rounding the Gaspé coast; as under these disturbed conditions, there are times when the current may be setting more or less on shore.

The current at other seasons.—The following description of the current is given by two fishermen who have lived for many years at Cape Gaspé, and have noticed the set of the currents while fishing off the Gaspé Coast and around Anticosti. They have also excellent opportunity during the winter to judge of the current from the movement of the ice off Cape Gaspé itself; as their point of view on Cape Gaspé is nearly 600 feet above the water. They state that the in-shore tidal current which runs up and down on this coast is seldom more than one mile or one and a half miles wide. Outside of this, the ice runs constantly outwards all winter, and no open water is visible. This continues as long as the wind is north or north-west, which is its prevailing direction in winter; but when the wind changes to south or south-west, the ice leaves the shore, and makes open water as far out as can be seen. There is no change in the speed of the ice towards spring; but the fresh water ice which then begins to appear is quite different from the winter ice and can be readily recognized. The current, however, is stronger in the spring of the year than in the autumn.

They believe that the current circles round, running outwards on the Gaspé side and inwards on the Anticosti side; and that it is assisted in turning by the set in Mingan Strait, which they consider to make inwards more than outwards.

CURRENTS IN CABOT STRAIT.

(I.) Cape Breton Current.—On the west side of this Strait for a width of some 20 miles from Cape North, there is a constant current flowing to the south-east. This is the most constant in one direction, in any part of the Gulf; as it is rarely checked under any conditions that occur. It is known, however, to be checked or reversed for a few days at a time by heavy south-easterly winds.

Direction, speed, and width.—The most usual or dominant direction of this current is between south and south-east (magnetic). Its speed is greatest near to Cape North, where it may be as much as two knots per hour. The width of the water flowing in the south-eastward direction, has been found to extend for twelve miles or more to the east of St. Paul Island.

Further out, in the middle of the Strait, the current was found to be very variable in direction, and usually weak.

The behaviour of the Cape Breton current in the summer season, from a number of observations made in the months of August and September, is as follows:—At an anchorage 9 miles S. E. from Cape North, in the middle of the width of the current passing between that Cape and St. Paul Island, the speed was found to range usually from ½ knot to 1½ knots per hour. After a strong north-westerly wind, which blew continuously for forty-eight hours with an average velocity of 24 miles an hour, the current here reached a speed of 2·25 knots. This is probably as high a speed as it ever attains at this distance from shore.

At an anchorage 10 miles N. E. from St. Paul Island, the speed was found to vary from a little over ½ knot to fully 1½ knots per hour.

Its direction at both the above points, was found to veer during the course of the day, from south-east to south-west and back to south-east. The regularity in the time of this change in direction makes it probable that it is tidal in its nature; but the observations were not continued long enough to establish any definite relation with the rise and fall of the tide, as recorded by the tide gauge on St. Paul Island. The greater speed of the current seems to occur during the fall of the tide, however.

Drift of ice.—The Cape Breton current carries out much Gulf ice in the early spring; and this serves to afford an indication of its direction. Many vessels are then engaged in sealing among it, and their masters are thus able to furnish reliable information. They state that from the northern end of the Magdalen Islands to Cape North the current although it may fluctuate, makes on the whole to the south-east. Vessels caught in the ice will drift outwards past Cape North, sometimes as far as the offing of St. Pierre Island.

There is reason to believe that this current is no stronger in the spring than at other seasons; although this is sometimes asserted.

This current continues to be felt along the sweep of the north-eastern coast of Cape Breton Island, sometimes as far as Scatari, before it mingles with the water of the Atlantic.

(II.) Current off Cape Ray.—On the eastern side of Cabot Strait, there is usually a movement of the water to the north-west, or inwards towards the Gulf. This is a continuation of a general set westward, which is felt along the south coast of Newfoundland, between St. Pierre Island and Cape Ray.

Direction, speed and width.—In steady weather, a current in this inward direction is felt for a width of 10 or 15 miles from Cape Ray, or even further.

In the month of August, at an anchorage 13 miles west of this Cape, the speed was found to range from ½ knot to nearly 1½ knots per hour. The direction varied between west and north; the dominant direction being north-west. The change in direction was less regular in time than on the other side of Cabot Strait; and no relation to the rise and fall of the tide could be made out.

Disturbance; and drift of ice.—There is evidence to show that this current is by no means constantly inwards. As, however, the water off the south coast of Newfoundland usually remains open and free from drift ice throughout the winter, this is in itself an indication that the general movement is westward; as the Atlantic water must then be warmer than the Gulf water. It is also stated that icebergs off St. Pierre Island will make westward, even against a north-west wind.

When there is ice in the spring season in the offing of St. George's Bay and off Cape Ray, the evidence goes to show that it comes from the opposite direction, with the general drift which makes across the Gulf from Gaspé towards Cabot Strait, and at times when this current or a branch of it, is driven further to the eastward than usual. It is apparently in this way that the outward drift of ice on the Cape Ray side is to be explained, as this undoubtedly occurs in the early spring of some years at least, and when certain winds prevail. The Sailing Directions remark that in changeable weather, vessels can reach as far north as Lark Harbour in the Bay of Islands, in any month; as it is only strong westerly winds which bind the ice in on the coast, and it soon clears away. The ice is thus brought there under conditions which make it an indication of disturbance in the current, as otherwise the water would remain open.

WEST COAST OF NEWFOUNDLAND.

In general, from Cape St. George to Rich Point, the movement of the water is north-eastward along this coast. Even when the current on the surface is checked, the under-current continues in this direction. It is thus evident that this is the normal direction of the current, when undisturbed.

The constant current.—From the Bay of Islands to Rich Point, the current is the most distinct and persistent; and it may there be termed constant. It is stated by two navigating lieutenants of cruisers of the North American squadron, who have had from two to three years experience on this coast, that the current in the summer season is always north-eastward when it is felt at all; and that it usually amounts to one knot. It is only intercepted by the flood and ebb tides running in and out of the larger bays on the coast.

The fishermen on this coast anchor their boats as much as 10 or 12 miles off shore, in about 30 fathoms of water. They have thus an excellent opportunity of observing the behaviour of the current. They state that its prevalent direction is to the E. N. E. parallel with the shore; it will run constantly in that direction for three or four days together; and on the whole it has that direction for rather more than two-thirds of the time.

The current is stronger near the shore and weaker further out. It is found accordingly that a schooner going south-west will make better headway with long tacks; but if going north-east, with short tacks inshore.

Behaviour of the current as observed.—The speed and direction of this current was observed in September at an anchorage opposite the straight shore, where it woul be unaffected by local influences. The point selected was 12 miles off Cow Head, which is 20 miles north-east from the mouth of Bonne Bay. The current was found to set almost always to the north-east, and very seldom veered in direction through a wider range than from N. N. W. to E. The speed is greatest while the current has its dominant direction to the E. N. E., but it was not found to exceed one knot per hour.

The current while thus veering in direction, may set directly off shore; and it may also set on shore for three or four hours at a time. When setting on shore, the speed was little over ½ knot per hour, at the offing of 12 miles, above mentioned.

Drift of ice.—Flat ice of about six feet in thickness, appears off Bonne Bay in January or February, and remains till the early spring. The movement of this ice serves to indicate the usual direction of the current on this coast; as it drifts north-eastward in one day as far as it drifts south-westward in three days, with the same amount of wind one way or the other. A schooner caught in the ice off Cape St. George at the end of March, drifted along the coast as far as St. Barbe in about ten days, a distance of 190 miles; which gives on the average the ordinary rate of about one knot.

Influence of the wind.—For 12 to 20 hours before the arrival of a south-westerly gale, the current sets more strongly in its usual direction. Before a north-easterly gale arrives, it slacks; although it may also become slack at other times. With long continued easterly winds it may be reversed in direction.

STRAIT OF BELLE ISLE

The current in this Strait is predominantly tidal in its character. When undisturbed by wind, the current runs east and west for a length of time which is nearly equal in each direction, and turns regularly in correspondence with the rise and fall of the tide. On the whole there appears to be a small balance or difference of flow in favour of the inward direction to the west.

Supposed inward flow.—There has been a wide-spread impression that the current in Belle Isle Strait ran constantly inwards, towards the Gulf of St. Lawrence. This inward current was supposed to be branch from the general Arctic current which runs southward along the outer coast of Labrador and Newfoundland. Such a current is still shown on some physical maps, as running in through Belle Isle Strait and finding its way out again through Cabot Strait into the Atlantic.

As this belief is unfounded, it is evidently very misleading to shipping.

As long ago as 1854 the true tidal character of the current in Belle Isle Strait was described in a report by Mr. M. H. Warren, addressed to the Colonial Secretary of Newfoundland. Mr. Warren had been more than twenty times through the Strait in sailing vessels, and thrice in a steam sloop; and as Superintendent of Fisheries for the Newfoundland Government, he had spent the months of July and August of the previous season cruising in the Strait, and had anchored several times in every harbour and also rowed in a boat from harbour to harbour. He was accordingly requested to report on the navigation of the Strait, and in the course of his report he says:—"The

tides in the Strait of Belle Isle are generally regular, flowing east and west; on the rising tide setting to the westward, on the falling tide to the eastward, alternately every six hours. When the wind prevails east or west several days, it influences the tides. Sometimes with a prevalence of east or west winds, on the change of the tide there is merely slack water."

On the Admiralty Chart the following remark is made :—"The movements of the water in Belle Isle Strait are made up of a general westerly set affected by tidal streams and winds. The resulting set may be in either direction." This remark gives little countenance to the theory of a constant inward flow; and is in itself sufficiently non-committal to cover almost any conditions.

(I.)—Character of the Current at the narrowest part of the Strait.—In July and September, 1894, the current was examined at anchorages seven miles eastward of Amour Point, where it is free from tide rips and local influences, and where the width is only 11 miles. The following summary describes its character :—

The current is fundamentally tidal in its nature. In moderate weather and during the prevalence of moderate westerly winds, it runs east and west with nearly the same strength. It attains at times a speed of two knots per hour in each direction.

During heavy and long continued wind, especially when easterly or westerly in the direction of the Strait, the tidal current which runs with the wind becomes stronger than the current against it; and eventually the current may become continuous in the same direction as the wind. It will still have a fluctuation in speed which corresponds with the tide.

While the surface current is thus affected by the wind, the under-current from five or ten fathoms downwards, will maintain its tidal flow for some time longer. This assists the surface current in regaining its tidal character when the wind falls.

The greatest speed of the current during heavy winds, at that season, was as follows :—Inwards to the west, 3.15 knots; and outwards to the east, 2·50 knots per hour.

As regards the two sides of the Strait, there is on the whole a tendency on the south side to greater tidal regularity; and on the north side to greater persistency of flow in one direction or the other. This is probably due to the greater depth or body of water on the north side.

Under-current.—In moderate weather, during the westward set of the current, the under-current was usually stronger than the surface current, by 5 per cent on the average; and during the eastward set, it was always weaker than the surface current, being only 70 per cent as strong on the average. Hence as regards the body of water from surface to bottom, the difference on the whole is in favour of a greater inward flow to the west. This is especially true on the north side of the Strait.

Current and tide.—During moderate weather, while the current ran with the greatest tidal regularity, the relation between these was as follows, in the central part of the Strait :—The flood setting westward, would either stop at high tide, or would continue to flow for some time longer; its greatest continuance being 2h. 35m. after the time of high water.

The ebb setting eastward, continued in that direction for a length of time varying from 40 minutes to 2h. 55m. after low water.

These variations between the turn of the current and the time of high and low water, were partly due to irregularity in the tides themselves at the time. On the average from twenty-eight observations, the turn of the current occurred at 1h. 45m. after high water, and at the same length of time after low water.

Such a relation it is important to obtain correctly. When the tide record itself, now being obtained from the tide gauge at Forteau Bay, becomes sufficient for the calculation of tide tables, it will enable the turn of the current, while undisturbed by wind, to be known from the time of the tide.

Drift of icebergs in relation to the current and tide.—The icebergs which are carried in through the Strait by the inward flow, less frequently return with the current in the other direction; as most of them ground or break up and melt in the Gulf. This probably accounts for the idea of a constant inward flow; as this is made visible by the bergs, whereas the outward flow may not be so.

In moderate weather, icebergs while drifting up and down the Strait, may make inwards on the whole; as there is some balance of flow in favour of the westward direction, especially in the under-current; and their motion necessarily depends on the movement of the body of the water as a whole.

As the size of the icebergs which enter the Strait is only limited by the depth of the water, many of them ground at low tide. Also, as the tidal current over-runs the time of high and low water, it is easily seen that the draught available for an iceberg is greater on the average during the period of westward current, than during the eastward current, outwards. Although the rise of the tide is only five feet, the bergs may thus pass over shoals or ridges on the bottom, in the one direction but not in the other; which also tends to favour their inward movement.

When the current is predominantly westward for a time, icebergs come in with it, if they are then numerous at the outer end of the Strait; but when the current is predominantly eastward, the Strait is likely to be free from floating bergs.

The presence of icebergs in the Strait cannot be depended upon however, as a reliable indication of the direction of the current at the time. It must rather be taken as showing the prevalent or average flow during the day or two preceding. Some inference may be based upon this, when compared with the direction and force of recent winds.

Water temperature.—The temperature of the water in the Strait does not afford any definite indication, either of the direction of the current or of the proximity of ice. This conclusion is based upon a large number of observations, from surface to bottom, and under varying conditions of the current.

Caution.—From the above characteristics of the current in Belle Isle Strait, it is clearly possible for a vessel to over-run its reckoning in either direction through the Strait. Also, vessels entering through the Strait should not assume that the current is necessarily in their favour in making the run westward to Anticosti; as it is possible that the set in the Strait itself and also in the eastern end of the Gulf, may be against them.

The current at other seasons.—In the spring and late in the autumn, the wind disturbance is greater; and the current in the Strait may consequently be more persistent n one direction or the other, than in the summer.

Reliable information as to the current at these seasons was obtained from two masters of schooners, who have had many years' experience in the Gulf; one of them for the last thirty years having made three trips each season in his schooner, sealing in the ice in the spring, cod-fishing in the summer, and herring-fishing in the autumn. In their experience, although the current in the Strait does turn, it runs longer and stronger eastwards than westwards; and thus makes outwards on the whole, even when the winds are easterly. On the other hand, they know that seals on the ice may be carried inwards through the Strait into the Gulf, during heavy north-easterly winds.

The following information is furnished by Mr. T. M. Wyatt, who has been light-keeper at Amour Point for 15 years, and also keeps a record of the wind; and by Mr. Charles Davis, resident at Forteau Bay and engaged in fishing in the Strait. In the spring of the year, the prevailing winds are easterly, and accordingly the current runs continuously inwards, and only slacks with the tide without turning. The duration of this westward current varies from year to year, but usually continues for one or two months in the interval between the beginning of April and the end of June. A strong west or north-west wind however, will make the current run out to the east. In the summer, the currents are less strong and not so persistent, and are more under the influence of the tides. In the autumn the winds are often easterly in the latter part of September and October; but perhaps more often westerly; and in either case the current is influenced by their direction. Later in the autumn north-west winds occur with colder weather. These winds continue to be prevalent during the winter months, and give the current an outward direction.

This statement must be qualified by the usual uncertainties attributable to the weather; and it is also to be noted that currents when continuous in either direction, are apt to be more persistent on the north shore, where these observations were made.

In March 1896, two schooners which were caught in the ice off Bonne Bay, drifted eastwards through the Strait, and were carried down the Atlantic side of Newfoundland to Notre Dame Bay.

On careful consideration of the best information obtained, the general conclusion is as follows:—The actual flow through the year, when the influence of the wind is included, appears on the whole to be little greater in the inward direction to the west, than outward to the east.

(II.) Current at the Eastern end.—The general Arctic current setting southward past the mouth of the Strait, is influenced by the tidal inflow and outflow of the Strait itself. It is found accordingly on the whole, that the greater inflow towards the Strait takes place on the northern side of the mouth, and the greater outward flow on the southern side.

Hence the icebergs which enter the Strait usually pass between Belle Isle and the Labrador coast. The general movement of the current at the mouth of the Strait, as shown by the drift of icebergs, is described in a pamphlet on the subject written by Captain Vaughan, who resided four years on Belle Isle. He states that for ten icebergs which enter the Strait, there are fifty that pass the mouth and go southward with the general drift of the Arctic current. The larger bergs also ground at the entrance of the Strait.

It is to be noted that on the Newfoundland coast from Cape Bauld to Cape Norman, there is an indraught towards Cook and Pistolet Bays. This may be due to the pressure

of the Arctic current on this shore, which by its position opposes the southward progress of the water.

For further description of the currents in this region, and the conditions met with locally, see 'Supplement to the Newfoundland and Labrador Pilot', Third Edition; corrected to August 1899.

(III.) Currents at the Western end.—The area between Rich Point and the western end of Belle Isle Strait, is intermediate between the constant current on the west coast of Newfoundland, and the tidal current of the Strait. The tidal element predominates however, and the current does not usually make in one direction more than the other on the whole. As a result, the currents are variable and uncertain in their direction, and cross-currents are frequent. When flat ice is present, it may make a considerable drift when the wind is with the current; but when against it, the ice stands and shoves.

The area in which such currents may occur, extends westward from the narrowest part of the Strait at Amour Point to a line through Rich Point running magnetic north to the west end of the Esquimaux Islands. Towards the western side of this area, the currents are usually less than one knot, and seldom exceed $1\frac{1}{2}$ knots; but towards the entrance of the Strait their strength increases, while in direction they are more nearly in the line of the Strait itself.

In the offing of the Esquimaux Islands, fishermen when anchored six miles from shore find that the current usually runs along the shore in one direction or the other; but there are times when it sets off or on shore for a whole tide.

There is also a cross-current which is sometimes found to run from Greenly Island south-eastward; and forms a strong set on shore towards Flower Cove.

Effect of the wind.—On a north and south line from St. John Bay to Esquimaux Islands, where the clear width is 32 miles, the current was observed at three anchorages at the end of July in 1894. During the seven days previous there had been 124 hours of westerly wind averaging 20 miles per hour, and only 48 hours of easterly wind averaging 19 miles per hour. After these prolonged westerly winds, the current set eastward throughout the whole width; and the thickness of the layer of water in motion, which was only from five to ten fathoms, was distinctly marked off from the water below by its higher temperature, thus indicating a wind drift. The speed of the current was $\frac{3}{4}$ knot per hour at the middle of the width, and 1.19 to 1.37 knots at the sides. This in the circumstances is likely to be as great a speed as ever occurs in an eastward direction. In the same locality at the end of August in 1896, the greatest speed observed in the offing of Rich Point was $\frac{3}{4}$ knot per hour.

THE NORTH SHORE OF THE GULF.

The Mecattina shore; from the Esquimaux Islands to Cape Whittle.—On this shore the general movement of the body to the water, when the direction of the undercurrent is also taken into account, was found to tend westward.

When the weather is calm, and also during easterly winds, the current on the surface will usually follow this general movement of the water to the westward. The actual current, under the influence of the prevailing winds from the westerly quarter, is very irregular however, and may set in almost any direction.

The direction in which the body of the water makes on the whole, is also indicated by the drift of icebergs. These have been seen as far west as the Mecattina Islands; and sometimes, though rarely, they reached Cape Whittle. Icebergs on this shore therefore, are carried westward more than twice as far as on the Newfoundland side, where they are rarely found beyond Rich Point.

Speed and direction.—In the summer season, the speed of the current usually ranges from $\frac{1}{2}$ knot to one knot per hour; and it may be in any direction. As between off-shore and on-shore directions, a set off shore is the more frequent.

The captains of trans-Atlantic steamships, in reply to circulars issued in the seasons of 1895 and 1896, report that the average current met with on the run from Heath Point to Greenly Island was as follows:—On thirty-two trips made between July and October there were *sixteen times* when there was no current appreciable; *nine times* the current set eastward, and *seven times* it set westward; the speed in each case ranging from $\frac{1}{4}$ knot to $\frac{3}{4}$ knot per hour on the average during the above run.

In the early spring, at Great Mecattina Island near the middle of this shore, it is stated by an old resident that the current runs in either direction, but is strongest to the westward. The ice when going westward, passes at a walking pace, or about three knots per hour. It is unlikely that the current in the open is ever as much as this. The fishermen not infrequently speak of a much higher speed; but it is always found on inquiry that this is over-estimated, or that they refer to local rips or tidal streams in confined channels.

From Cape Whittle to the East end of Anticosti.—The current in Mingan Strait was found to be tidal, and to run with nearly the same strength in each direction. There is accordingly no through current to be expected in the channel north of Anticosti.

Where the currents are so slow, the influence of the wind is the more considerable. From observations at an anchorage mid-way between Cape Whittle and Heath Point, made continuously day and night for five days in the month of July, the current was found to set in all directions with a low speed; the dominant direction being with the winds which were most continuous at the time. Thus when a period of several days is taken as a whole, it is found that the greatest amount of set has taken place in the same general direction as the greatest total mileage of wind; but at any particular time, the direction of the current is seldom the same as the wind which is blowing locally.

As winds from the westerly quarter are the most prevalent at any time, it is probable that the surface current usually has an outward tendency. This accords with the experience of Captain Macauley of the Dominion Line; who states that in crossing from Heath Point to Cape Whittle, vessels are set more to the southward by north-west winds, than to the northward with south-east winds.

At an anchorage 18 miles off Cape Whittle a continuous record of the direction of the current was obtained during five days in the month of July, and again during four days in August. The current was found to veer completely around the compass in a period of about sixteen hours on the average. The speed of the current did not exceed one knot per hour in any direction.

It thus appears that the general tendency of the water to move westward, when combined with the influence of the prevailing wind in the contrary direction, has for its result an actual set which is nearly equal in every direction.

Off the east end of Anticosti the current was found to veer very much in the same way. It was observed repeatedly at two anchorages at 13 and 24 miles S.E. from Heath Point; and would veer completely around the compass, or back through a half circumference. While thus veering in direction, the current would sometimes set directly towards or from the end of the Island of Anticosti, for as much as two hours at a time. The speed in the month of July was not more than one knot in any direction; but in September it was sometimes over one knot per hour. This was probably due to the influence of the heavier winds in that month.

Tidal influence.—There is reason to believe from a close study of the manner in which the current veers, and the directions in which it holds the longest, that these may be due to tidal influence. In the case of these currents which are well out in the offing, the tidal relations that have been made out, are found chiefly to govern the movement of the under-current; and they have relatively little influence on the surface current, except in very calm weather.

Shore currents in the channel north of Anticosti.—The direction of the current at $1\frac{1}{2}$ miles off East Cape, was noted every two hours during daylight for thirty-three days in the months of July and August. It ran north and south, parallel with the shore; but was quite irregular as regards the length of time in each direction. On the whole, from the total of 231 observations, the set was found to be southward for two-thirds of the time. It is stated by men acquainted with Anticosti, that it is only on the short length of coast, from Table Head to East Cape, that the current has a dominant set of this character.

At Natashquan Point, the current at two miles from shore, was observed in a similar way for seventy-two days in the months of July, August and September. Its direction was usually north-west or south-east, along the general bearing of this coast; although it sometimes veered two points or more from these directions. The change of direction showed more correspondence with the tide, than at East Cape. On the whole, from a total of 627 observations, the set was south-eastward for two-thirds of the time.

The 'Constant currents' shown locally on the Admiralty Charts at these points, must therefore be taken to mean that the current sets in the direction indicated about twice as often as in the contrary direction.

Mingan Strait.—An examination of the currents in this Strait was made in the month of July at its narrowest part; between North Point of Anticosti, and Niapisca Island, one of the Mingan group. The current proved to be tidal. It runs north-westward through the Strait with the rising tide, and south-eastward with the falling tide. It often veers considerably from these directions, however. The speed in the open Strait, puring neap tides, does not amount to as much as $1\frac{1}{2}$ knots per hour in either direction.

The difference in the amount of set each way, as shown by the surface current during calm weather, is in favour of the inward direction; being on the whole 24 per cent more to the north-west than to the south-east.

West end of Anticosti.—It is stated by Mr. A. Malhouin, light-keeper at West Point, that the current on the south of Anticosti in that vicinity, is much weaker than in Mingan Strait and is more under the influence of the wind; and accordingly it sets along shore either south-east or north-west. In the summer the usual direction is north-westward. At times when the current on the south shore is south-eastward, it appears

to divide at West Point while the tide is falling in Mingan Strait; but while the tide is rising, the currents meet on the north shore within eight miles of West Point.

In the spring, the ice on the south shore drifts with the wind and current to the south-east, except when the wind is easterly, which is not frequent. The ice is not over six feet thick, except when packed or in shoves.

SOUTH SHORE OF ANTICOSTI.—The currents here are usually weak and irregular. As observed in the months of July and September, at anchorages about six miles from shore in the offing of Ellis Bay, South-west Point, and South Point, the current was found to veer and back irregularly and set towards all points of the compass. The speed usually varied from $\frac{1}{2}$ knot to one knot per hour.

The current would thus set off or on shore as much as in other directions; and would be on shore for a period of one to three hours at a time. These periods came irregularly with the veering of the direction of the current, but usually occurred twice in the twenty-four hours. The current however was then weak, and did not often exceed $\frac{1}{2}$ knot per hour.

It is stated by fishermen having a long acquaintance with these coasts, that for some distance both ways from South Point, they have found the current to set obliquely on shore from a southerly direction; more especially during S.W. and S. winds, and with a rising tide.

THE MIDDLE OF THE OPEN GULF.

The nature of the current in the open, is indicated by observations obtained on the Orphan Bank. The speed ranged from $\frac{1}{2}$ knot to a little over one knot per hour. At another anchorage 29 miles E. by S. from Bird Rocks, the average speed during nine hours was $\frac{3}{4}$ knot. The direction of the set was very varied.

The influence of the tidal current from Chaleurs Bay, can be felt as far as 30 miles out from Miscou Island, at the mouth of the Bay.

Off the north and south ends of the Magdalen Islands, at about six miles from shore, the currents are more distinctly tidal. They run alternately in north-westward and south-eastward directions, with a speed which is sometimes over one knot per hour.

The captains of the Black Diamond Line of steamers, running from Montreal to Sydney, Cape Breton, in reply to circulars issued in the seasons of 1895 and 1896, have reported the average currents met with on the run across the Gulf, in the summer season from June to October, to be as follows :—

Between Gaspé and the Magdalen Islands, on 17 trips reported, there were *ten times* when the current set south-eastward, at a speed ranging from one knot to $1\frac{1}{2}$ knots per hour on the average of the run; *twice* it set north-westward; and *five times* it ran south-west or north-east as a cross-current, the speed in these directions being only from $\frac{1}{2}$ knot to one knot on the average.

Between the Magdalen Islands and Cape North, on 16 trips reported, there were *nine times* when the current set south-east or eastward, at an average speed of $\frac{1}{2}$ knot to one knot; *twice* it set north-west at only $\frac{1}{2}$ knot; *twice* there was a cross-current; and *three times* there was no current appreciable.

The above result is also important as an indication of the dominant direction of the set across the middle of the Gulf.

NORTHUMBERLAND STRAIT.

In this Strait the tide has a large diurnal inequality, which makes the two tides in the twenty-four hours very unequal in height, at certain times in the month. At Charlottetown, one tide in the day may have a range of seven feet and the other a range of only three feet. This feature of the tide is more marked in Northumberland Strait than anywhere else in the Gulf of St. Lawrence.

The tidal currents in the Strait are affected by this; and accordingly there will probably be a strong set in each direction during the rise and fall of the one tide, and a weaker set during the other tide of the same day. This alternation occurs when the moon is near its maximum declination, north or south of the equator; and it is also more accentuated at the solstices. But when the moon is near the equator, the two tides in the day become equal; and the tidal currents also.

With regard to the relation of the current to the tide, the following note is given in the Sailing Directions:— "The tidal streams were observed in general to change their directions soon after it was high water or low water by the shore; but not unfrequently there were exceptions to this which it would be difficult to account for with certainty. Strong winds in the Gulf greatly influence the strength and direction of the streams in the Strait, as well as the height to which the tides rise."

The tide tables for Charlottetown and Pictou now issued by this Survey, will thus afford some knowledge as to the time of the turn of the current in the Strait.

PART II.

The foregoing part has been restricted to a description of the currents on the surface, which a seaman may expect to find in each locality in the Gulf of St. Lawrence.

The following part is now added for the benefit of those who may desire to obtain some intelligent grasp of the conditions in the Gulf area, and the causes which influence the currents in moving as they are found to do; and who may wish to know something of the general relation of the waters in the Gulf area to the St. Lawrence River and the Ocean; on which the work of this Survey has thrown considerable light.

In the language used, technicalities will be avoided; and no descriptions will be given of the methods and appliances employed in tracing out the currents, although some of these had not before been used at sea, or were specially adapted to meet the conditions in the Gulf.

Surface current in relation to the under-current.—It may be thought at first sight that the direction of the under-current has no bearing upon the movement of the water as it affects navigation. In such a region as the Gulf of St. Lawrence, however, the currents in the summer months are all very moderate in their speed, usually ranging from half a knot to one knot per hour; and their direction on the surface is accordingly much influenced by the wind. It was found in these circumstances that the movement of the under-current at 20 or 30 fathoms, often showed more definite characteristics; as for example a tendency to make constantly in some one direction, or to vary with the tide. The wind is thus a disturbing element; and the under-current being more in accordance with the normal conditions of the locality, will come up to the surface as soon as the disturbing influences which have been acting on the surface of the water, cease to operate.

It may be unfortunate from the point of view of the navigator, that it is the surface of the water to a depth of 5 or 10 fathoms, which is so readily and so frequently disturbed; but on the other hand it is clear that it is essential to make a careful investigation of the under-current in order to understand the surface current itself. The study of the under-current is also necessary, if any hope is entertained of arriving at the general circulation in the Gulf, or the true relation of its currents to the causes which influence them.

The general causes which act upon both the surface and the under-current, but often affect them differently are:—1. Tidal influence. 2. The influence of the wind and barometer. 3. A cause of a wider character which shows itself as a tendency in the current to set constantly in some one direction.

When a period of some length is considered as a whole, and the under-current is also taken into account, it becomes possible to trace the general circulation of the water; which depends upon a greater movement in some dominant direction rather than in other directions, when long averages are taken.

The primary tendency in the surface current is thus to follow the direction which the general circulation has in the locality in question; but this tendency is disturbed and often overcome by the influence of the tide and the wind. The tidal influence shows itself chiefly as a veer in the direction of the current, which is either through a limited range, or completely around the compass; and it is also probable that the tides themselves are irregular in some localities, owing to the interference of the tidal undulation from Belle Isle Strait with the main tide which enters through Cabot Strait. When the wind remains in one quarter and has any considerable strength, the drift which it gives to the surface water soon extends to a depth of five fathoms or more, and its influence thus makes itself felt throughout the thickness of the surface layer which affects shipping. As a rule these influences are all acting at the same time; and it is their combined effect which gives rise to the actual behaviour of the surface current.

For examples of the relation of the under-current to the surface current, see Report of Tidal Survey, January, 1897, Table II; and accompanying explanations in that report.

Temperature and density.—The two characteristics chiefly relied upon in tracing the movement of currents, are the temperature and density of the water.

In the Gulf of St. Lawrence, the surface temperature in the summer season usually ranges from about 50° to 65°, and in proceeding downwards this temperature gradually falls, until at a depth of 40 or 50 fathoms it is only 31° to 34°, or practically at the freezing point. Where the greater depths are met with, the water below this again, is found to be appreciably warmer. There are considerable areas however, in which the depth is less than 50 fathoms, and where the conditions are accordingly restricted.

The best observations to ascertain the amount of change in the temperature of the surface water with the season, were obtained at a series of points, five miles apart, on each of the following lines:—(1.) From 30 miles off Heath Point, to Cape St. George on July 6. (2.) From a point off Cape Whittle, to the offing of Cape St. George, on August 3. (3.) Same line as No. 1, run a second time on September 28. The results were as follows:—

(1.) July 6. From 49½° to 51½°. Average = 50°.93.

(2.) August 3. From 50° to 54°. Average = 52°.68.

(3.) September 28. From 52° to 54½°. Average = 53°.62.

Is appears, therefore, that in general, the temperature of the surface water merely rises with the progress of the season; and it is also natural that the water should become warmer to a greater depth as the season advances. Even this has its limitations, however; as at a depth of 50 fathoms no greater rise in temperature has yet been found than from 32° to 34°, between the month of June and the end of September.

At all three angles of the Gulf, the coldest water forms a layer between the depths of 30 and 50 fathoms. In the vicinity of Belle Isle Strait, the same low temperatures are also found at these depths; although there the temperature towards the surface is relatively lower as a rule, than in other regions. It is probable that this cold layer extends very generally over the Gulf area; and it cannot, therefore, be taken as an indication of direction of movement of the water.

Below this cold layer, in the deep channel of the Gulf, the temperature from 100 to 200 fathoms is found to range very constantly from 38° to 41°. This result was obtained in Cabot Strait, and also between the Gaspé coast and Anticosti, 220 miles further in from the Atlantic, along the deep channel. This deep water, from such indications as have been obtained, appears also to be entirely quiescent, and to have therefore little direct relation to the currents in the Gulf, in so far at least as they affect navigation.

With regard to the density, it may be stated broadly, that throughout the north-eastern portion of the Gulf the average surface density ranges from 1·0235 to nearly 1·0245; while in the south-western portion, the density is below 1·0235, ranging usually down to 1·0220, and falling in the Gaspé Current itself to 1·0210. The dividing line between these two portions of the Gulf, runs approximately from South-west Point, Anticosti, to a point in the middle of Cabot Strait. The densities in the border region near this dividing line, naturally vary to some extent. The density of the north-eastern portion is practically the same as in the open Atlantic; as it was there found to range from 1·0237 to 1·0242, as shown by seven determinations made at the end of June, off the south and south-east coasts of Nova Scotia.

This result is important, in showing that the lower densities found in the south-western portion of the Gulf of St. Lawrence are confined to that side; and this further confirms the conclusion that the general set or drift across the Gulf, as shown by the water of lower density, is in the direction of a line from Gaspé to Cape Breton. On the other hand, the endeavour to obtain some differences locally, which would correspond with the various directions of the current, was without result; although a large number of temperatures as well as densities were taken at the various anchorages for this purpose.

The deep water as found from samples taken at depths of 100 and 150 fathoms, both in the vicinity of Gaspé and in Cabot Strait, ranges in density from 1·0254 to

1·0261. The density of this deep water is very interesting in affording an explanation for the otherwise anomalous fact that the colder water at 50 fathoms is found to float upon it. It also corresponds with the density at similar depths, off the coast of Nova Scotia.

(See results of temperatures and densities, to a depth of 150 and 200 fathoms, given in tabular form in Reports of Tidal Survey, April, 1896, page 7, and Tables A, B, C, D, E, and F, and Plate VIII; and January, 1897, page 26. Also general diagram of surface densities, Report of April, 1896, Plate III.)

Influence of the wind.—With regard to the effect of the wind in giving the current a dominant set in its own direction, the best examples met with during the three seasons, are derived from observations obtained in the open waters in the vicinity of Heath Point and Cape Whittle, at the anchorages A, B, and C, of the season of 1896. The observations were taken every half hour continuously day and night for periods of 130 hours, 107 hours, and 90 hours respectively: the wind being measured by an anemometer on board. The results when reduced to tabular form, make evident the relation between the direction of the wind and the set of the surface current. The depth to which the wind disturbance was felt, was also ascertained. (See Report of Tidal Survey, January, 1897, pages 22 and 23.)

A noteworthy example of the depth to which wind disturbance may extend, was detected by observations in 1895 between the Magdalen Islands and Cape Breton. (See Report of Tidal Survey, April, 1896, page 11; and Plates III. and VI.)

There is one relation between the wind and the strength of the current which appears to apply chiefly, if not entirely, to currents which are fairly constant in their direction. Such a current is found to run more strongly before the wind comes, if the wind is to be in the same direction, and it slackens if the wind is to be against the current. The fishermen when anchored in their boats, take these indications as warnings of the approach of heavy weather. This change in the current before heavy winds, is found to occur on both the south and west coasts of Newfoundland, and has also been noticed on the north shore of the Gulf of St. Lawrence. It appears to be due to the action of the wind during storms, in first holding back the water and then releasing it, and the low-pressure area of the storm as it passes along also increases the result. It is also probable that the effect is more distinct in the case of confined waters, as it is very noticeable on the Great Lakes. It is from analogy with the conditions which obtain there, that this explanation is suggested.

The effect of the wind in overcoming a fairly strong tidal current, has already been described in referring to Belle Isle Strait. The conditions under which the most persistent flow in each direction occurred, are given in Report of Tidal Survey, October, 1895, pages 12 and 13.

It must not be too hastily assumed, however, that the wind alone is the cause of the movement of the water in the same direction; as it appears probable that the tendency of the current to flow in the same direction as the wind, is due to the combined influence of the wind itself, and to difference in barometric pressure over wide areas. When the pressure is exceptionally high or low over a large area like the Gulf of St. Lawrence, the effect should be all the more noticeable; as the corresponding flow has to take place through comparatively narrow entrances or straits. In such straits, while the direct effect of the wind would produce primarily a surface drift, it is possible that difference of pressure would cause a more even flow throughout the whole depth.

Drift of ice in relation to the current.—The currents are often well indicated by the drift of ice; but in order to infer correctly the set of the current from its drift, it is necessary to distinguish between the different kinds of ice met with, and their relation to the movement of the surface of the water, and to the under-current, respectively. In the early spring, numbers of small vessels are engaged in seal fishing; and information of importance can thus be obtained, if the relation of the ice to the current is understood.

The ice met with is of three kinds:—(1) Berg ice, or the true icebergs which come into the Gulf through Belle Isle Strait. They are also found off the south coast of

Newfoundland, nearly as far west as Cabot Strait. (2) Flat or pan ice, forming fields or in broken pieces, usually not more than 6 feet in thickness, but sometimes as thick as 10 feet. This often jams or shoves along the shore or between islands, and may form masses 20 feet or more in thickness, but it can never be mistaken for berg ice. In this flat ice a distinction is sometimes made between 'Northern ice,' which finds its way in through Belle Isle Strait under certain conditions, and 'Gulf ice,' which forms in the Gulf itself. As the effect of the wind and current upon it is the same in either case, the distinction is not of importance in this connection. (3) River ice, from the St. Lawrence River and its estuary. This is also flat ice, and in the Gaspé region it can be readily distinguished by its appearance from the Gulf ice.

The berg ice, from its great depth in the water, will evidently move with the undercurrent; and it will not be appreciably affected by the wind. These bergs do not necessarily indicate the direction of the current as affecting shipping, except when the surface current has also the same direction. They show in reality the average direction the current has, between the surface and the depth of their draught. This draught is limited to about 30 fathoms by the depth of Belle Isle Strait. They are thus of much value as an indication of the general movement or circulation of the water.

The relation of the flat ice to the wind and current requires some little consideration. It is, of course, just as true of this ice as of the berg ice, that the greater part is under water; but, as it is almost always in broken pieces, more or less piled and with upturned edges, the wind has a much greater hold upon it in proportion to its total weight, than on the berg ice. Even when this is allowed for, its depth in the water still gives the current a greater hold upon it than the wind has. For example, if such ice is drifting with a current in a given direction, and the wind is blowing across that direction at right angles, the ice will seldom be set more than two points, or three at the most, off the true direction of the current. When the ice becomes soggy or water-soaked and loses its edges, as it does later in the spring, it will set still more correctly with the current.

When the surface current itself is moving in the direction of long-continued or prevalent winds, as it often does in the Gulf, the flat ice naturally follows the same direction too. Also in regions where the current is tidal, and the ice in calm weather would drift as far in the one direction with the flood tide as in the other direction with the ebb, the direction in which it makes on the whole will depend upon the wind. It is probably for these reasons that it is so often said that the ice drifts with the wind; although this merely expresses the fact, without distinguishing between the relative influence of the wind and the current upon it.

There is also a direct effect which the ice has upon the strength of the current in regions where the direction of the surface drift is under the influence of the wind. The broken and upturned edges of the ice give the wind a much greater hold upon the water than it otherwise would have. Hence during long continued winds the speed of the current is appreciably greater than if the ice were not present. This is undoubtedly the explanation of the common belief which is expressed by saying that "the ice makes its own current." It may be well to recall that the weight of the ice itself is the same as the water which it displaces; and therefore, the wind has no greater mass to set in motion in producing a surface current than if the ice were to melt and re-fill the hollow which it makes in the water; while the presence of the ice gives the wind a better hold than it would have upon the surface of open water, free from ice.

There is one condition of the ice which may prevent it from showing correctly the drift of the water. When it is set against an island or headland and packed together for a long distance out, with open water beyond, it may circle round as on a pivot. The outer edge of the pack may thus make a long sweep very different in its path from the true set of the current; and its movements also become irregular, as vessels caught in such ice which are near together in the evening, may be ten or fifteen miles apart in the morning.

GENERAL CIRCULATION IN THE GULF.

A knowledge of this general circulation is important to mariners, as it includes all the more constant currents, and it also shows the direction which the surface current

tends to take when undisturbed. Although there are few instances of currents in the Gulf area which run steadily enough to be termed constant, we have yet found it possible from continuous observation or long experience to arrive at a dominant direction for each locality; or the direction in which the current runs more frequently, and in which therefore, the water makes on the whole.

In reviewing the movements of the water, with a view to tracing the general circulation in the Gulf, it is the principle of the balance of flow which is the most evident. Wherever a current of a constant character occurs, there is a corresponding return current to make up for it. Thus in Cabot Strait, the outflowing water in the Cape Breton Current is balanced by the inflow at Cape Ray; the north-eastward current on the west coast of Newfoundland is balanced by the contrary direction of the movement on the opposite shore; and we have fairly good indications of a return flow to compensate for the Gaspé Current.

It is this balance of flow which points to the nature and direction of the circulation of water in the Gulf. If we begin to trace it from Cabot Strait, where the balance between the Gulf and the Ocean takes place, the inflow at Cape Ray appears to diffuse itself more or less widely over the central part of the Gulf, but it regains its strength further north on the west coast of Newfoundland, and makes a deep bend into the north-eastern angle of the Gulf, and returns westward along the north shore. On reaching Cape Whittle, it still makes westward; and, whether as an actual set, or by displacing water which comes more directly from Cape Ray, it appears to work around the eastern end of Anticosti, and so compensates for the outflow of the Gaspé Current from the estuary of the St. Lawrence. This current after rounding the Gaspé coast, makes south-eastward as a general set or drift across the Gulf to the western side of Cabot Strait; and its waters there leave the Gulf in the outflow of the Cape Breton Current.

It also appears that the whole of the balance or compensation in the Gulf currents takes place at the surface and in ordinary under-currents, which do not probably extend to a greater depth than some 50 or 60 fathoms. There is nothing, therefore, to show the necessity for any appreciable movement in the deep water from 60 to 80 fathoms downward, which lies in the deep channels of the Gulf. Where direct observations have been obtained, this deep water appears to lie quiescent, without any movement that can be detected.

The Current in Belle Isle Strait, in relation to the Gulf area as a whole.—On account of the tidal character of the current in Belle Isle Strait, it is clear that no great volume of water can enter the Gulf of St. Lawrence from that quarter.

The tidal character of the flow in this Strait is described in Report of Tidal Survey, December, 1894; where the relation of the current to the tide, the temperature of the water, and the drift of icebergs, is fully explained. A diagram showing the flow of the current in the two directions as observed, is also given in Report of Tidal Survey, April, 1896, Plate I.

During the summer season, the current flows in the Strait with a speed which is nearly equal in each direction; and there is only a difference in favour of inward flow to the west, which on the whole does not probably amount to more than a moderate percentage. It is perhaps possible that in the early spring the preponderance of inward flow may be proportionally greater than at other seasons. There is some evidence to show that the incoming water may then penetrate the Gulf as far as Bonne Bay on the west coast of Newfoundland. But no reasons have been found for supposing that this water passes completely round the west coast of Newfoundland and finds its way out into the Atlantic through Cabot Strait, between Cape North and Cape Ray, in accordance with the theory which has been more or less accepted up to the present time. All the indications are against this theory, as they show that any general current across the extent of the Gulf must lie in an entirely different direction. It may be allowable therefore to sum up briefly the reasons for this conclusion.

The water in Belle Isle Strait is exceedingly clear. It is also very cold, and when flowing in the inward direction, its temperature as late as September is below 45° for the average of its depth from surface to bottom. Its density is as high as that of any water found within the Gulf, being on the average 1·0244 at the surface.

The water in Cabot Strait is quite different from this in its character. The greater part of the width of that strait is occupied by water which has the milky-green colour of ordinary sea water. The out-flowing current in Cabot Strait is on the side next to Cape Breton, or the further side from Belle Isle. This outflowing water has also a distinctly brown tinge; its surface temperature ranges from 55° to 65°; and its average density to a depth of 10 fathoms from the surface is 1·0230; and as far down as a depth of 20 fathoms it is still both warmer and fresher than the Belle Isle water. If, therefore, the Belle Isle water has any influence on this current, it must be indirect; for even if the water itself does not reach Cabot Strait, it might still be possible that a greater inflow through Belle Isle Strait would cause a greater outflow through Cabot Strait. Even this measure of influence cannot, however, be definitely asserted.

There is not only this difference in the character of the water in these two straits, but also a want of connection between them. On the west coast of Newfoundland the current sets north-eastward, or in the contrary direction to that which the theory supposes; and around Cape Ray the water makes inwards on the whole.

It might still be supposed, however, that any water entering through Belle Isle Strait would be most likely to pass out at Cabot Strait as a cold under-current along the bottom. The total depth of Cabot Strait is 250 fathoms; the coldest water forms a layer between the depths of 30 and 50 fathoms, and below this the water is again warmer but with a higher density, which ranges from 1·0254 to 1·0261. As this cold layer occurs in other parts of the Gulf area also, it cannot be taken as an indication of any special direction; and the characteristics of the deep water from 100 fathoms downwards show how different it is from the Belle Isle water. The indications so far as obtained, also show that the deep water from 100 fathoms downwards is entirely quiescent.

There is, therefore, no confirmation to be found for the theory that a constant current enters the Gulf by Belle Isle Strait and leaves again by Cabot Strait; but on the contrary, all the evidence met with, is directly against it.

The St. Lawrence River in relation to the outflow from the Gulf.—It can hardy be doubted that the low density of the water in the Gaspé current is to be attributed to the outflow of the St. Lawrence River; and we are thus able to trace the influence of this water as far as Cape Breton, where it finally mingles with the water of the Ocean. The volume discharged by the St. Lawrence has been measured above Lake St. Peter at different seasons; and with the addition of the Richelieu, St. Maurice, Saguenay, and other tributaries along its estuary, the total volume of fresh water discharge would probably amount in all to 340,000 cubic feet per second. This volume of fresh water will mingle with sea water for which we may assume a density of 1·0240; as this may be taken to represent either the mean density of Atlantic coast water to a moderate depth, or the density of the salter water in the Gulf itself. Under these conditions, the fresh water of the St. Lawrence would be sufficient to furnish a stream of water reduced to the lower density of 1·0230 which would be twelve miles wide and 68 feet deep, and moving with a speed of one knot per hour. This would represent the average density of the Gaspé Current, and would probably be an approximation to its average speed and its volume; and such a comparison may therefore serve to illustrate the way in which the conditions may be accounted for, if the data themselves were more closely known.

It is to be noted however, that as regards volume, the St. Lawrence River is almost insignificant as compared with the outflow of the Gaspé Current. The depth or thickness of this current was ascertained from measurements of the under-current taken in the offing of Griffin Cove at four different times, at which the surface speed varied between one and two knots. The mean of the four determinations gives the following percentage ratios for the under-current at different depths:—

Surface, actual speed	1·23 to 1·83 knots per hour.	
At 10 fathoms	77 per cent of surface velocity.	
At 20 "	38 " " "	
At 30 "	29 " " "	

This rate of decrease indicates a depth of about 45 fathoms as the total thickness of the current. This current, whether it flows near the coast or in the middle of the passage, has usually a width of about 12 miles. We may therefore consider its volume to be represented by a body of water of this width, with a mean depth of 30 fathoms, and moving with an average speed of 0·68 knot per hour, throughout this depth.

Such a current has a volume forty-three times greater that the St. Lawrence River. The volume of the Cape Breton Current also, is probably much the same. These outflows must therefore be replaced by a return movement at the entrance to the Lower St. Lawrence, somewhere in the Anticosti region; and also by a return flow from the Ocean into the Gulf area; as the discharge of the St. Lawrence furnishes less than 3 per cent of the amount required in either case.

(See density sections and diagrams of the Gaspé and Cape Breton currents, in Report of Tidal Survey, April, 1896, Plates III to VIII.)

Current across the Gulf area.—The general connection of the Gaspé and Cape Breton currents was made evident when it was ascertained that the water of lower density kept to the south-western side of the Gulf. The observations of the current in the open, and the reports from steamships aboved cited, also accord with a general movement of the water towards the south-east; as this is the more usual direction, and the currents which are found at times to run across this prevailing direction, are to be attributed to the influence of the tides and the wind.

As to the route taken by the water in traversing the Gulf from the Gaspé region to Cape Breton, it seems fair to conclude from the evidence furnished by the density observations, that the greater proportion finds its way eastward between the Magdalen Islands and Prince Edward Island; while a certain amount may also pass north of the Magdalen Islands, on the line from Bird Rocks to St. Paul Island. That some water passes round both ends of the Magdalen Islands on its way to Cape North is also confirmed by the steamship reports in that region; as the currents from the north-west and south-west towards Cape North, correspond with these two routes respectively. It is probable also that some of the water may come from Northumberland Strait, as the water there is also low in its density.

(For a discussion of the probable reasons why the water of lower density keeps to the south-western side of the Gulf, see Reports of Tidal Survey, April, 1896, pages 14 and 15; and January, 1897, page 36.)

Balance of flow in Cabot Strait.—The volume of fresh water from the St. Lawrence as already explained, may be sufficient to dilute the sea water to the low density found in the Gaspé Current or in the corresponding current flowing outward through Cabot Strait; but the total volume of water which actually leaves the Gulf is vastly greater than the volume of fresh water which it receives from the St. Lawrence River. The volume so leaving the Gulf must therefore be replaced by water which enters it from the Ocean.

The current which usually makes inwards on the east side of Cabot Strait, may be sufficient to compensate for the outflowing water of the Cape Breton Current; although it is also possible that the outflow from the Gulf may be partly made up for, by the difference of flow in the inward direction through Belle Isle Strait; which in some years may be considerable in the early spring. The relation of the current in this Strait to the Gulf as a whole, has already been explained; as well as the probable amount of inflow at Cape Ray, in continuation of the general westward tendency of the water along the south coast of Newfoundland. The quiescence of the deep water in Cabot Strait has also been pointed out, in this connection.

It may be well to note however, that although the outflowing water of the Cape Breton Current is much warmer in the summer season than the incoming Atlantic water, it is not so at all seasons of the year. While it is probable that the total result is on the side of loss of temperature to the Gulf area, it would require extended observations throughout the year to ascertain the amount of loss, and the probable effect in consequence upon climate in the surrounding regions.

(See temperatures of Cape Breton Current from the surface to forty fathoms, given in tabular form, in Report of Tidal Survey, December, 1894; pages 25 and 26.)

North-eastern arm of the Gulf.—It is not clear what becomes of the current which passes in at Cape Ray. As a rule there is no appreciable current off St. George's Bay, and very little from Cape St. George to the Bay of Islands. We cannot thus trace this inflowing water as an actual current, but it is probable that it makes to the north-eastward, and diffuses itself over the Gulf in that region, because we find that the density of the water throughout the north-eastern portion of the Gulf in the same as in the open Atlantic, and this density could not be so maintained without some inflow of this character.

Further north on the west coast of Newfoundland, from the Bay of Islands to Rich Point, the current is distinct, setting north-eastward. The under-current has this direction even more persistently than the surface current; and at a depth of 30 fathoms the speed is still half as much as on the surface. There is no other locality in the north-eastern arm of the Gulf, where the movement of the water is so definite and constant in one direction.

The prevailing winds over the Gulf area, which are south-westerly in summer and north-westerly in winter, may have an appreciable influence in maintaining the current on this coast, and in carrying it further into the north-eastern angle of the Gulf before it returns.

It is more than probable that the water which makes westward along the north shore, is a return current corresponding with the north-eastward set on the Newfoundland side. There is no other direction from which this water can come, as any inflow that there may be through Belle Isle Strait is quite insufficient to keep up the supply. A large volume must make to the westward, if this is in reality the usual direction of the under-current from about 15 fathoms downwards, where the total depth is seldom less than 40 fathoms.

The water must make across from the Newfoundland side to the north shore in the area lying between Rich Point and the west end of Belle Isle Strait. On the western confines of this area there is a constant current setting in from the south-west, and another setting out to the westward, while on its eastern side there is the strong ebb and flow of the Strait itself. There may also be times when long-continued winds give the surface current a drift which is either eastward or westward according to its own direction. As the depth ranges from 30 to 70 fathoms, it is sufficient to allow the water to make across to the northern side as an under-current, as it is quite possible that it does. The irregular character of the currents in this area, is thus accounted for.

On the west coast of Newfoundland the surface current and the under-current have the same direction; but in the return current on the north shore the direction is maintained chiefly by the under-current, while the current on the surface is not infrequently to the eastward. The reason of this must be that the prevailing winds are westerly, and they are with the direction of the one current, and against the other; and thus often reverse its surface drift.

Although the current on the Newfoundland side is thus the more distinct, the north shore current is the better known, as it lies more directly on the route of the Atlantic steamships, and that coast is also more frequented by fishermen.

(A full account of the currents in this arm of the Gulf is given in the Report of Tidal Survey, January, 1897.)

Return flow in the Anticosti region, to compensate for the Gaspé Current.—It has been pointed out that the volume of the Gaspé Current is vastly greater than the discharge of the St. Lawrence River, and that there must be a return flow somewhere in this region, to make up for it. Where this takes place, it has not been easy to determine definitely; but a good deal may be inferred from all the indications obtained, when these are considered together.

At the wider end of the channel north of Anticosti, it is probable that the current on the surface usually has an outward tendency to the south-east; corresponding with the prevailing winds which are from the westerly quarter. This is also indicated by the direction of the current on the two sides, at Natashquan Point and East Cape, as already explained.

As there is no evidence of any through current in this channel, the outward tendency of the surface water must originate in the channel itself; and it appears to be balanced by an inward tendency in the under-current. The current which sets westward along the north shore, on reaching Cape Whittle makes on the whole to the north-westward. This dominant direction is more marked in the under-current than on the surface; and this inward trend of the current around Cape Whittle is to be looked upon as an indraught to make up for the outflow on the surface.

In Mingan Strait, at the other end of the channel, although the current is tidal and nearly equal in each direction, the balance of flow is in the inward direction to the north-west; which is also in accord with the inward tendency of the under-current at the mouth of the channel. Whether the two movements are continuous or not, it is clear that the balance of flow in Mingan Strait helps so far to make up for the outflow in the Gaspé Current.

Although at East Cape, the surface current makes outwards near the shore, this does not indicate the general movement of the water in the vicinity of the east end of Anticosti. At anchorages as far in the offing as 13 and 24 miles S. E. of this Cape, the body of the water was found to make on the whole to the westward. It is more than probable that this water continues westward, and that it also contributes to the return flow which compensates for the Gaspé Current. The temperature and density of this water do not furnish any positive indication to show where it comes from; and it may possibly be drawn from the central part of the Gulf, where the water coming in at Cape Ray diffuses itself, or more probably it may make its way across from Cape Whittle, in continuation of the westward movement along the north shore.

It may therefore be concluded that some water makes inward through Mingan Strait; and some also makes inward at the eastern end of Anticosti, and may continue to work inward along the south shore of that island. This would accord with the frequent on-shore set of the current on the south side of Anticosti, near its eastern end. It would also appear that the inward movement occurs either at the surface or as an under-current at a moderate depth; as in the channel between Gaspé and Anticosti which has a depth of 150 fathoms, no movement in the deep water could be detected.

MOVEMENTS OF FISH, IN RELATION TO TEMPERATURE AND DENSITY OF THE WATER.

It is probable that the temperature and density of the water and the direction of the currents, may have important bearings upon the movements of fish, which as yet are imperfectly understood. This opinion is held by the countries bordering on the North Sea; and the information afforded by the investigation of the movements and other characteristics of the water, are there used as a basis in arriving at the reasons for the distribution and migration of fish at different seasons. This information has its chief application in the North Sea to the herring fishery; and yet a practical return is expected for the outlay which is made in obtaining it; and the investigation is of such importance that arrangements are being discussed for international co-operation amongst the countries bordering on the North Sea in carrying it on. In our fisheries, the cod and mackerel have a greater importance relatively than the herring; which would warrant the expenditure of larger sums in proportion to increase the catch by such investigations.

As an example of the importance of knowing where cod are to be found, and why they prefer one region to another in different seasons, it may be mentioned that in 1896 fishing schooners were returning from Labrador in September with half cargoes, while within the Gulf we found on the surveying vessel that cod were everywhere abundant throughout the summer on the 30 and 40-fathom banks, which no schooners were taking advantage of.

It is held by fishermen that fish are never caught while the water is clear; and its clearness must have some relation to physical conditions which could be ascertained. It is also known that the cod are caught in shallower water in the spring, and further from shore as the season advances. This may depend more directly on the movements of the herring or capelin which they follow; but these fish may themselves be influenced in

their movements by the temperature or other characteristics of the water, which may differ at different times. The depth at which the layer of coldest water occurs in the Gulf of St. Lawrence, found between 30 and 50 fathoms in the summer season, may have a bearing in this connection ; as the fish have usually a preference for cold water.

It may also be noted that at the greater depths of 150 to 250 fathoms the bottom, as shown by samples brought up by the anchor, is soft mud from brownish-blue to slate colour ; and the marine life there, judging by such specimens as came up, consists chiefly of sea-pens and other stalked creatures, which root themselves in the muddy bottom. There does not therefore appear to be at these depths much food of an inviting character for fish. An examination of such conditions might well prove useful, in view of the large annual value of the Canadian fisheries.